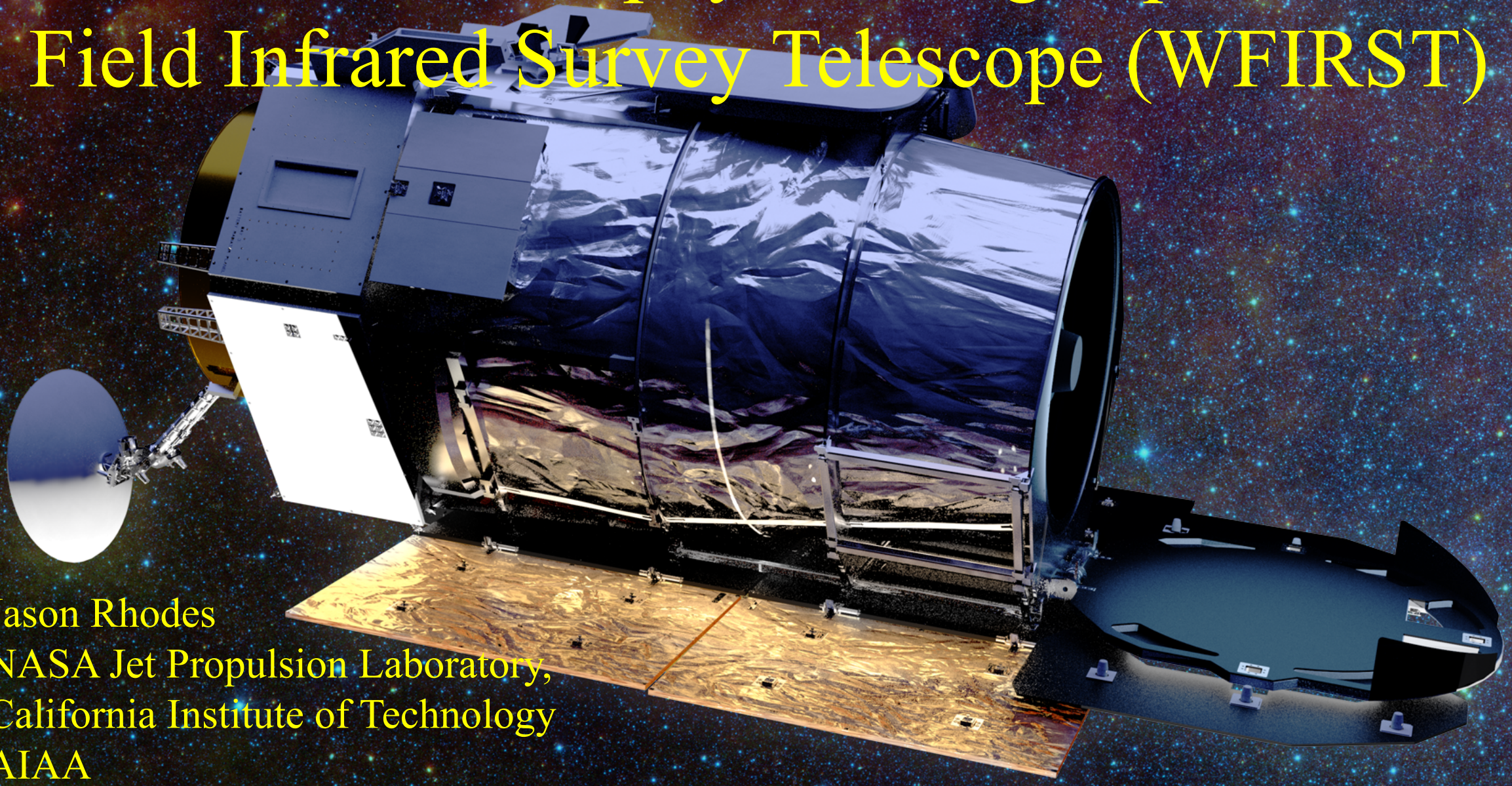
NASA's Next Astrophysics Flagship: The Wide Field Infrared Survey Telescope (WFIRST)



Jason Rhodes
NASA Jet Propulsion Laboratory,
California Institute of Technology
AIAA
September 18, 2018

#NASAWFIRST

©2018. Government Sponsorship Acknowledged The decision to implement the WFIRST mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

ASTROPHYSICS

Decadal Survey Missions

LRD: 2019

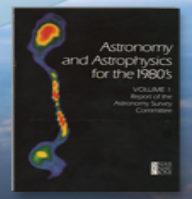
LRD: 2020s

2003

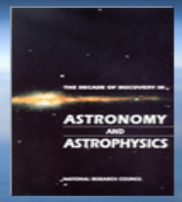
1999

1990

1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



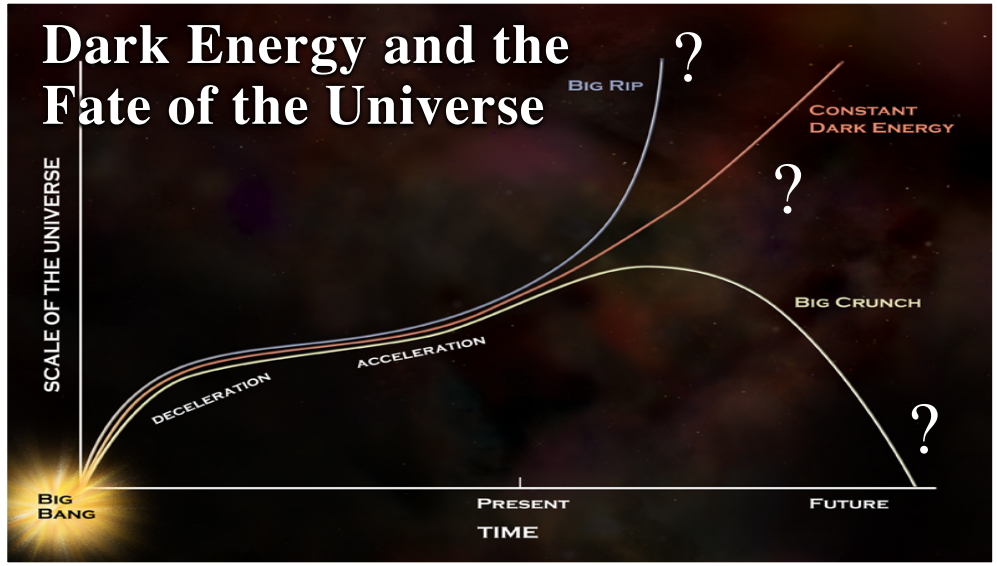
1991
Decadal Survey
Spitzer

2001
Decadal Survey
JWST, SOFIA

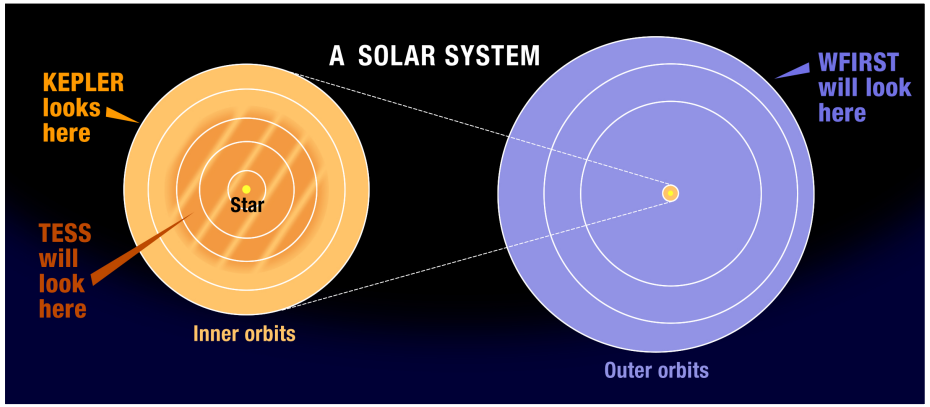
2010
Decadal Survey
WFIRST

WFIRST
WIDE-FIELD INFRARED SURVEY TELESCOPE
DARK ENERGY • EXOPLANETS • ASTROPHYSICS

Guidance from NWNH

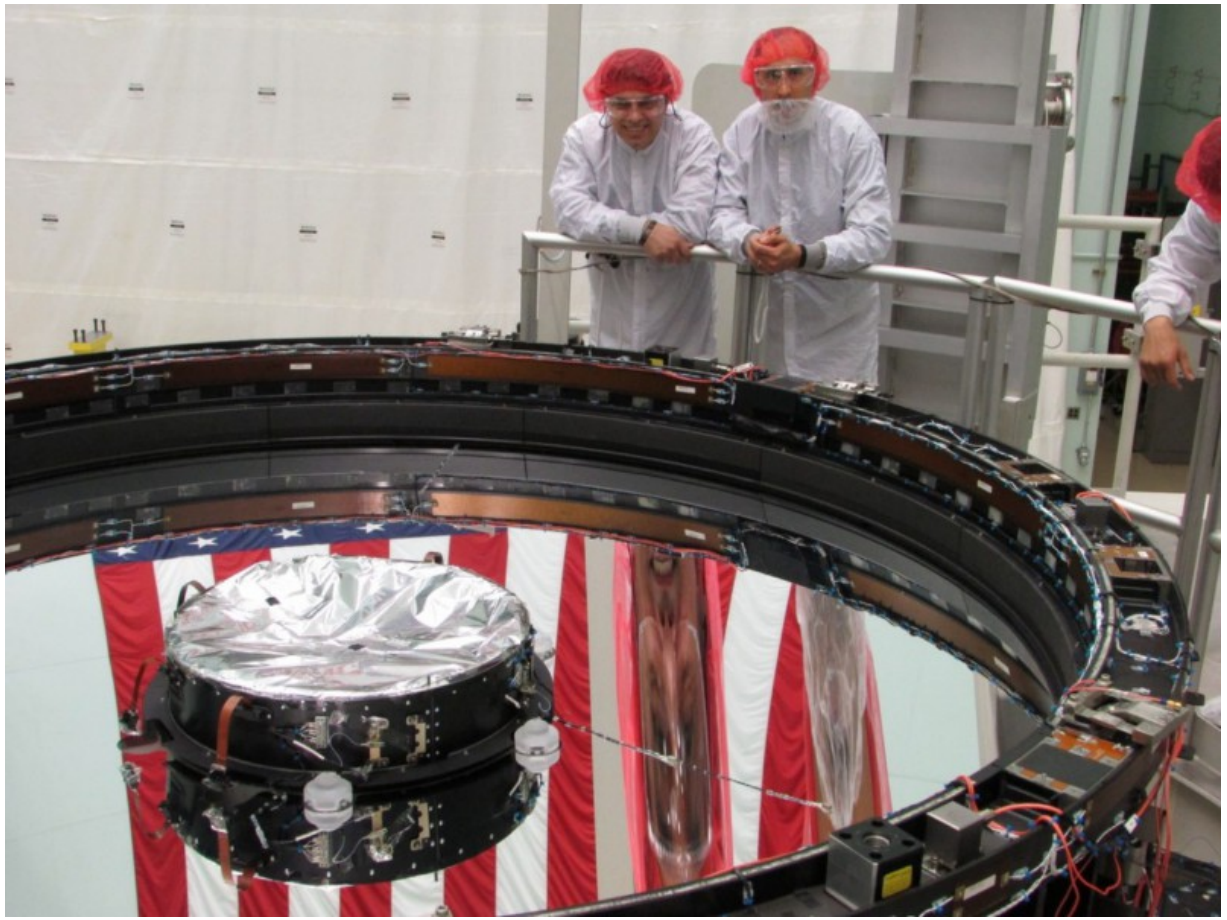


The full distribution of planets around stars



WFIRST Status

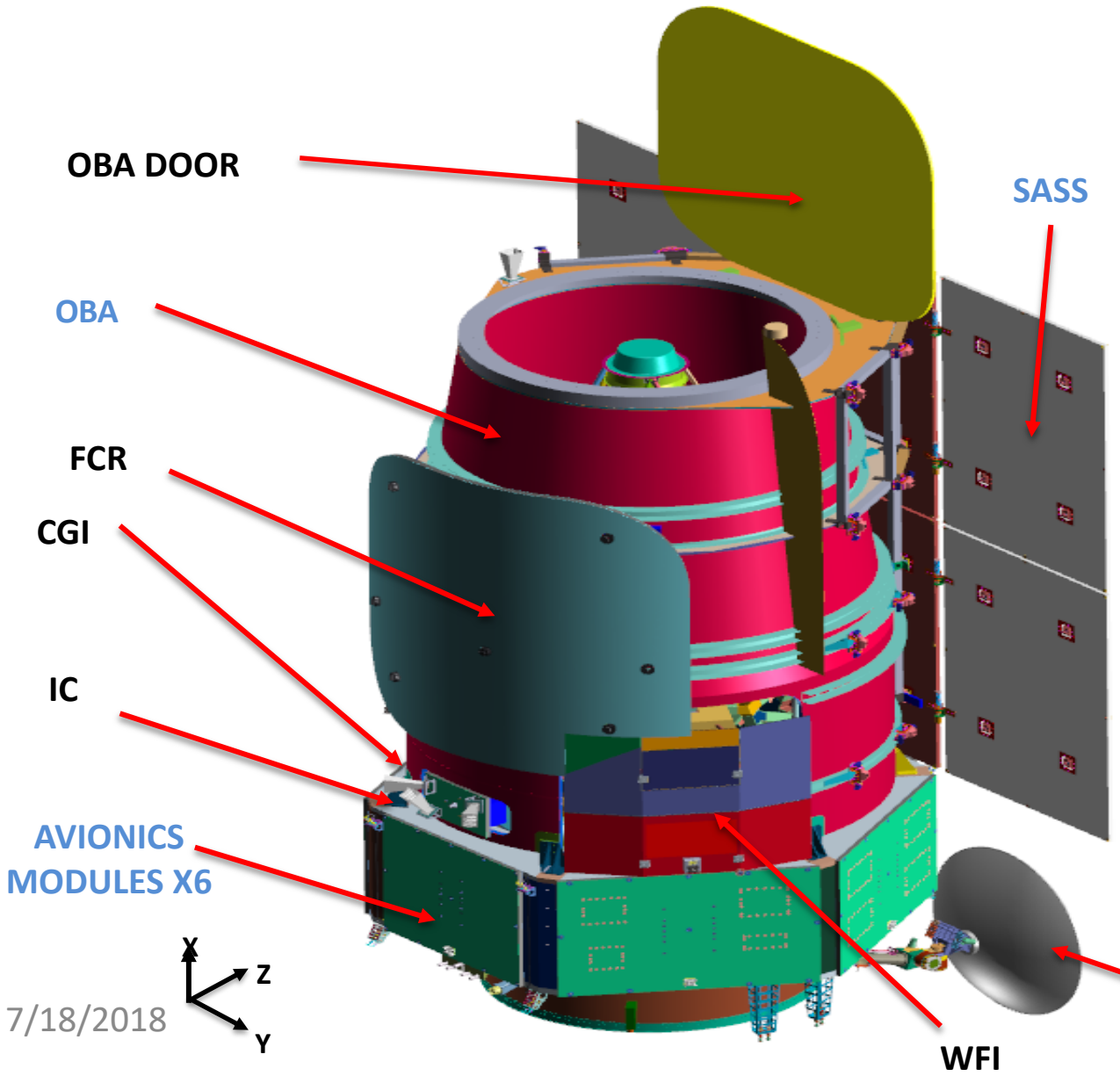
- Uses repurposed 2.4 m telescope from the another government agency
- Three science pillars: DE, exoplanets, infrared surveys
- Science done with Wide Field Instrument (WFI), with 18 H4RG detectors



Harris Corporation / TJT Photography

- Coronagraph Instrument (CGI) is a tech demo that will be ~1000x better than previous coronagraphs
- Designed to be Starshade ready
- Designed to be serviceable
- 5 year primary mission at L2
- 10+ year extended mission possible

WFIRST Observatory Concept



Key Features

Telescope: 2.4m aperture

Instruments:

- Wide Field Imager / Slitless Spectrometer
- Internal Coronagraph with Integral Field Spectrometer

Data Downlink: 275 Mbps

Data Volume: 11 Tb/day

Orbit: Sun-Earth L2

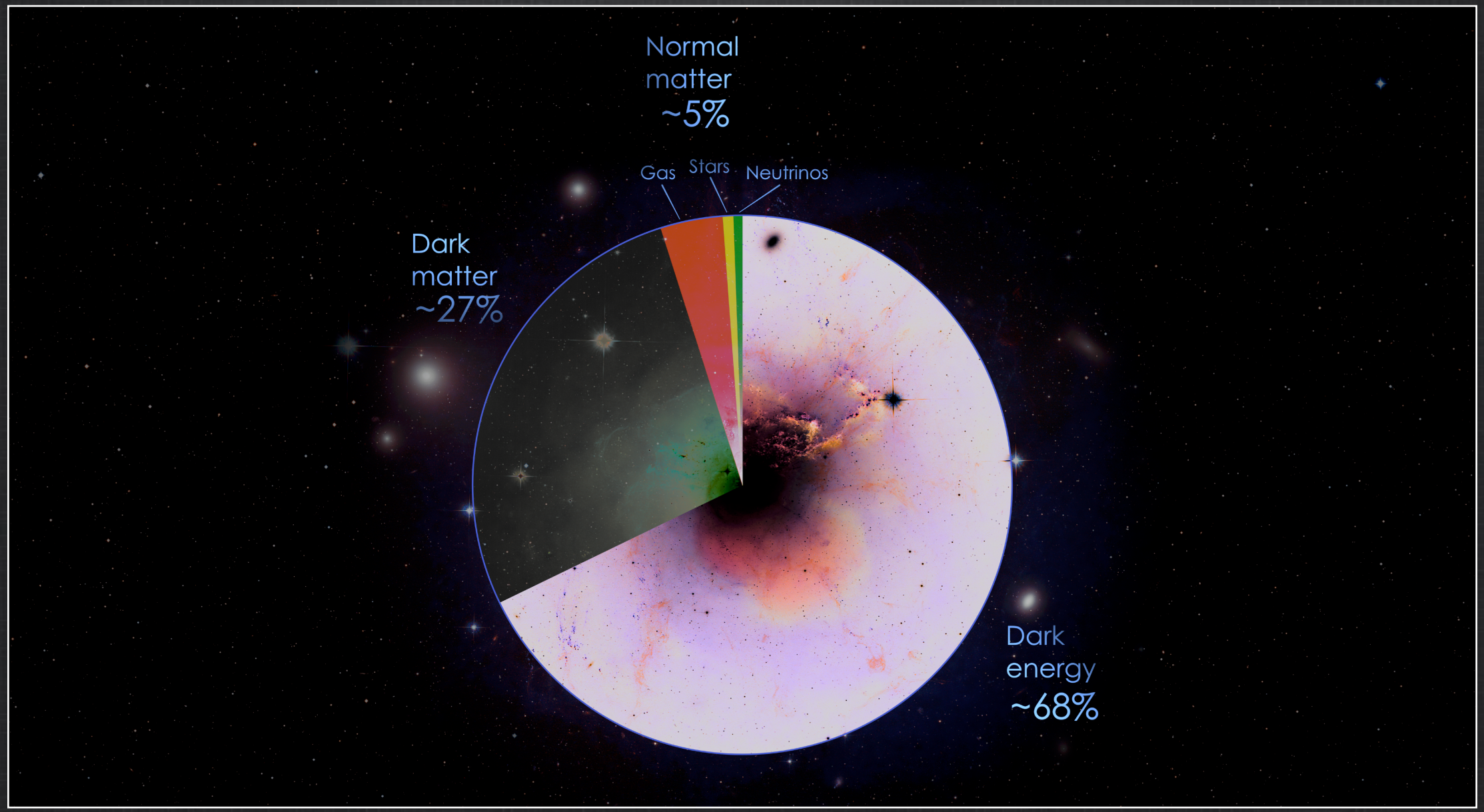
Launch Vehicle: 4 options

Mission Duration: 5 yr, 10yr goal

Serviceability: Observatory designed to be robotically serviceable

Starshade compatible

The Universe as a Pie Chart

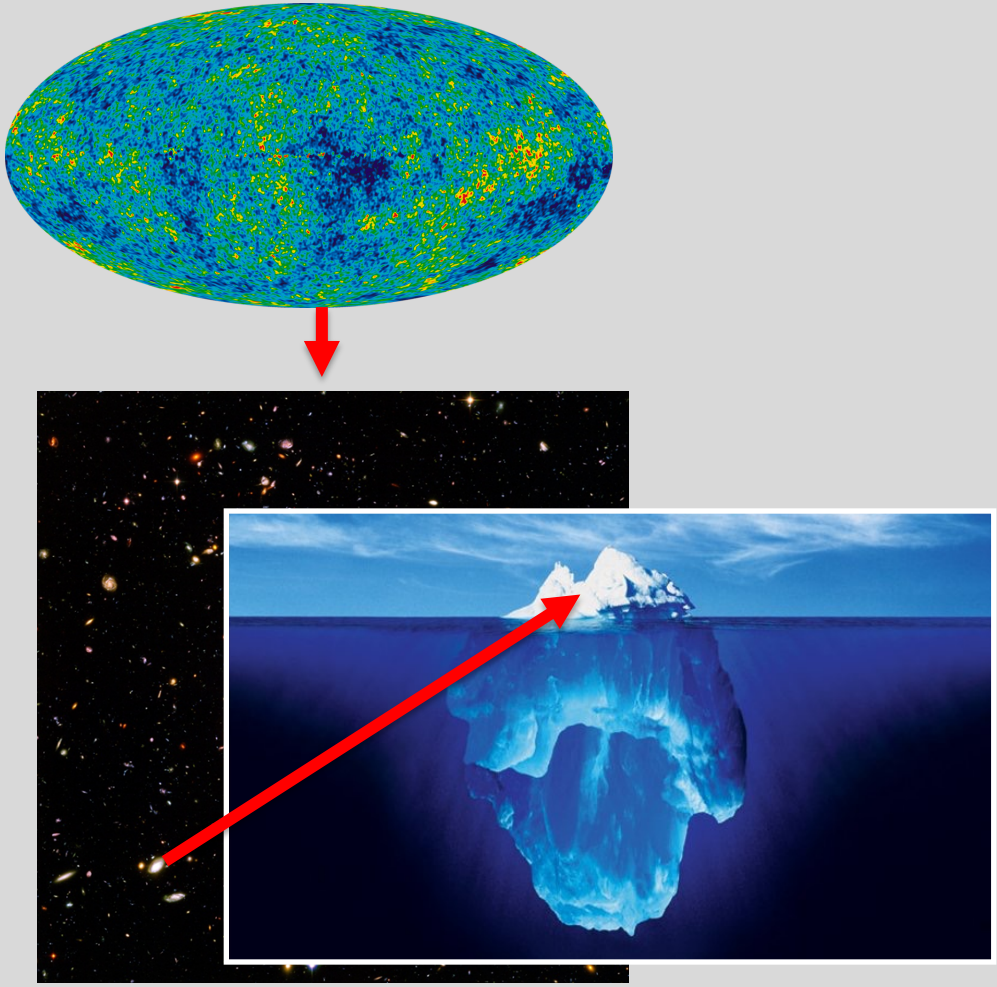


Consequences of DE

Dark Energy affects the:

- Expansion history of the Universe
  - How fast did the Universe expand?
  - Also called the geometry of the Universe

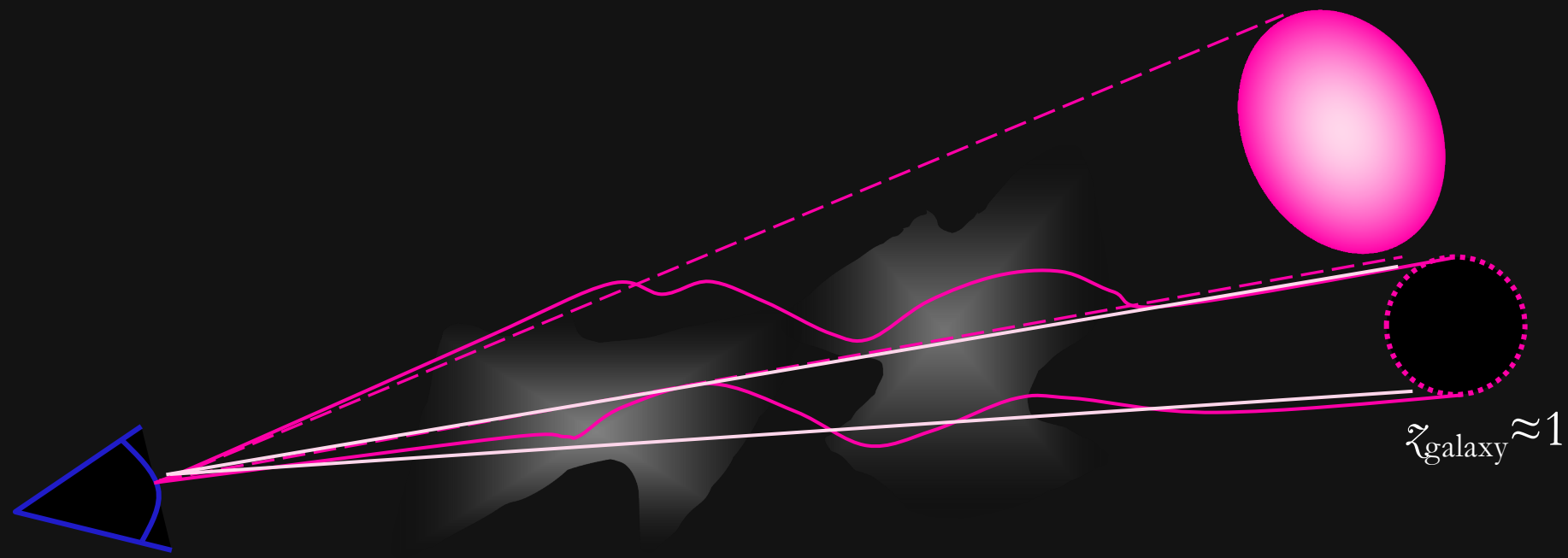
- Growth of structures
  - How do structures (which are mostly dark matter) evolve and grow over time
  - Attractive gravity competes with repulsive dark energy



If Einstein's General Relativity is wrong, modified gravity theories could explain the accelerating expansion.

This would change the above effects differently, *so we must measure them both!*

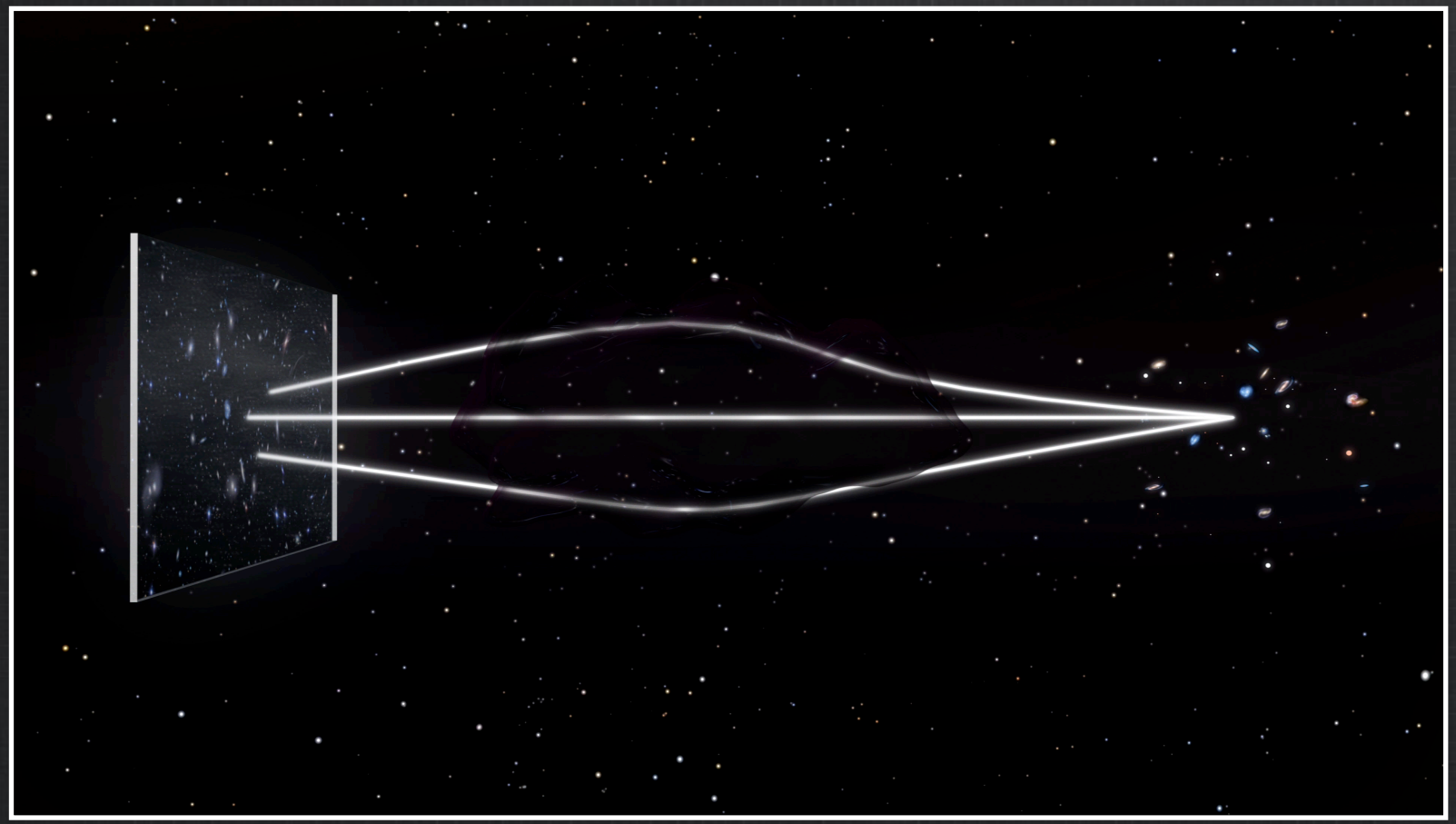
Gravitational Lensing

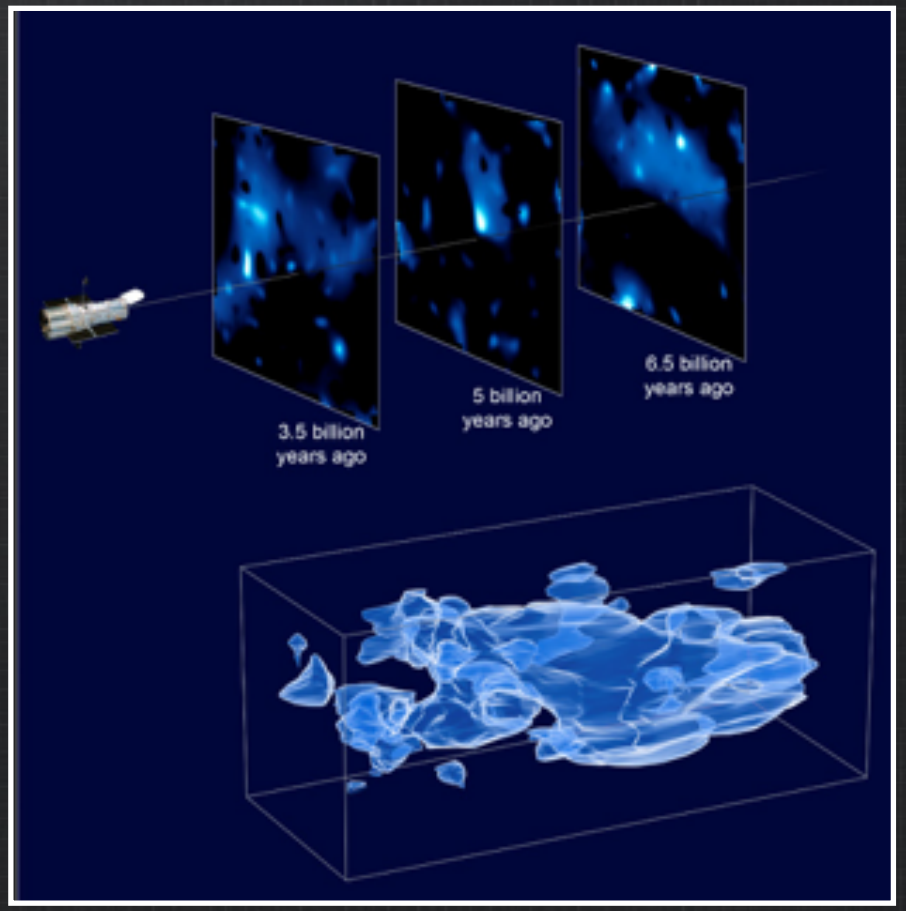


If there is any intervening dark matter, light follows the distorted path (exaggerated). Background images are magnified and sheared by ~2%, mapping a circle into an ellipse. Like glass lenses, gravitational lenses are most effective when placed half way between the source and the observer.

WFIRST will

measure galaxy shapes to map dark matter and measure the growth of galaxies over the Universe's life

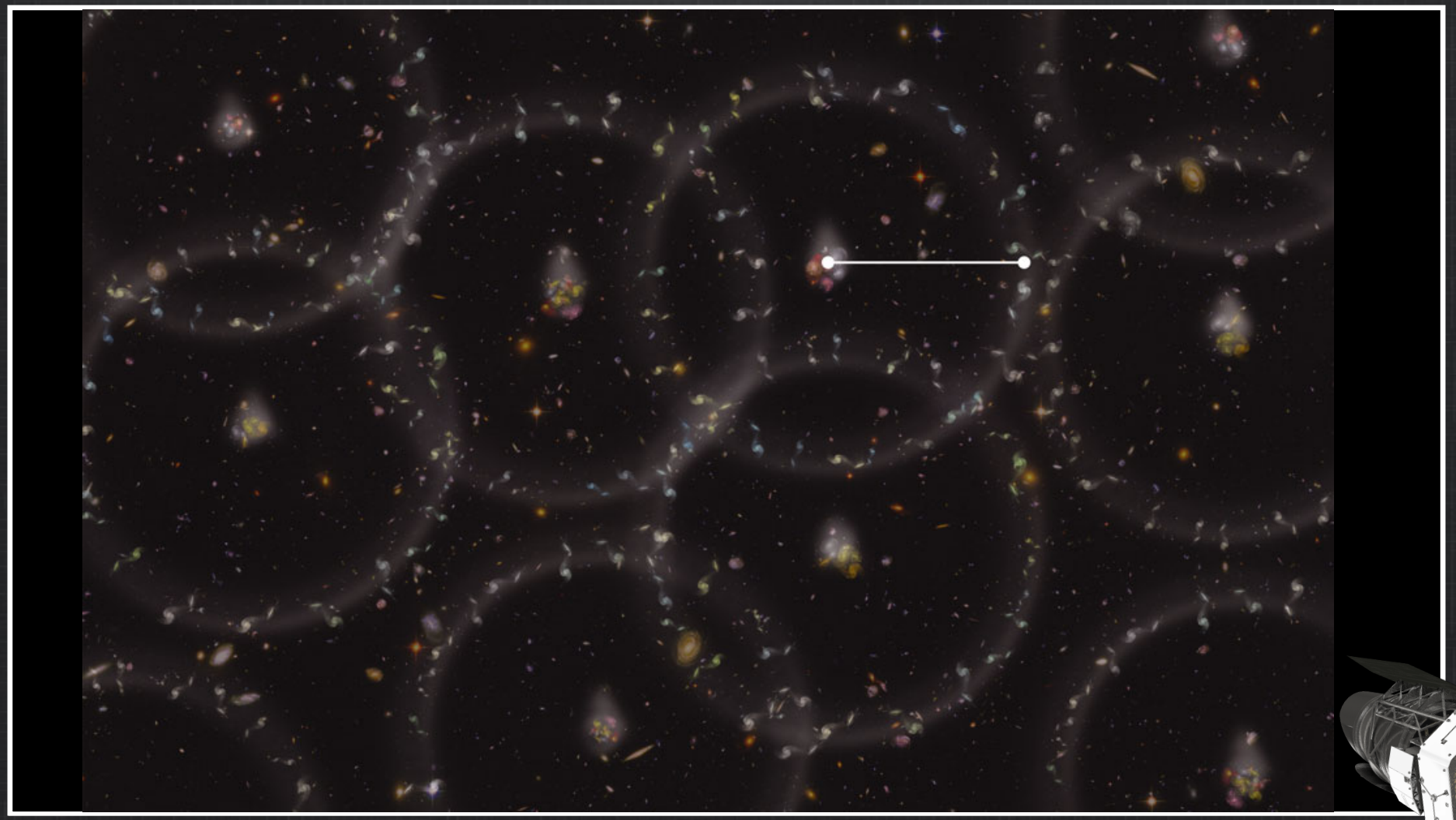


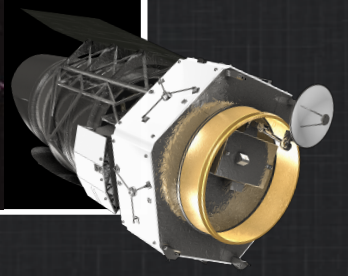


From Massey, Rhodes, et al 2007

WFIRST will

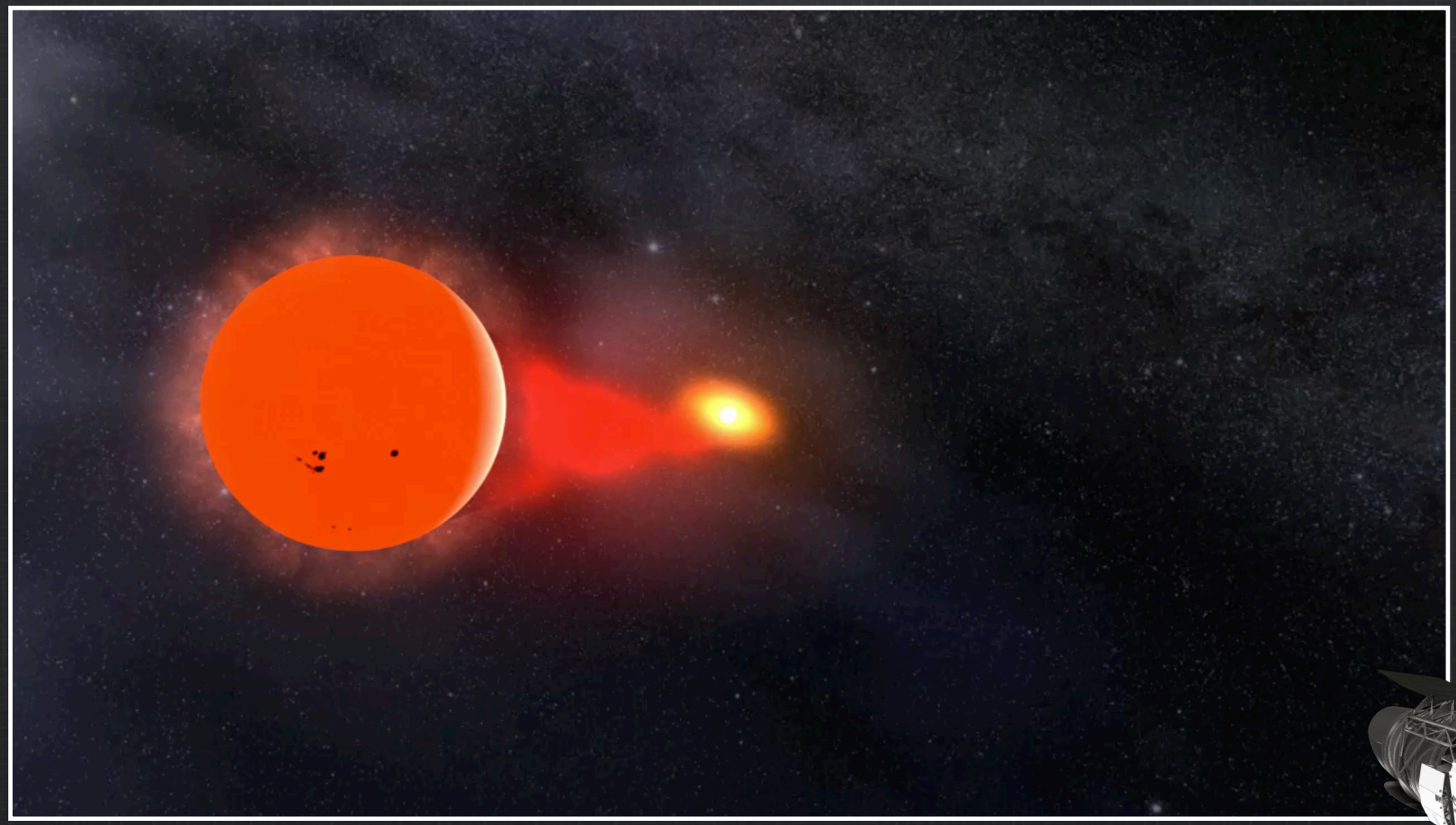
map the positions of galaxies to establish a cosmic standard ruler to measure the Universe's expansion history

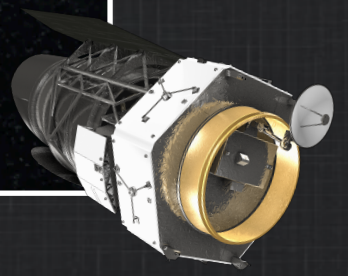




WFIRST will

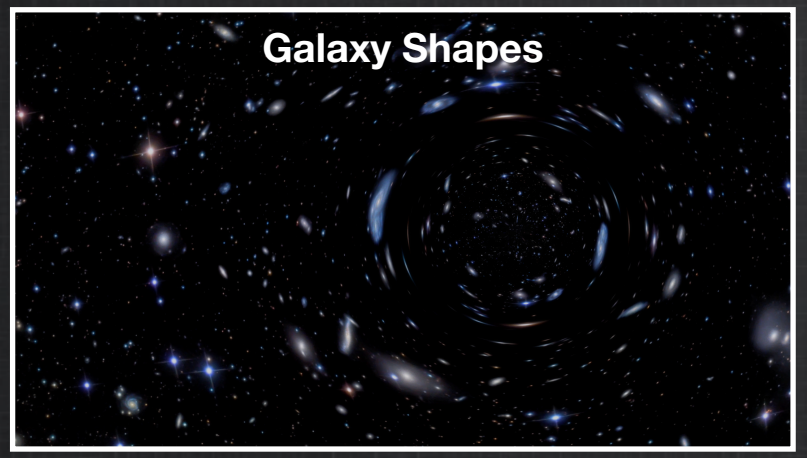
discover exploding stars (supernovae) across cosmic time
to establish precise distances to galaxies

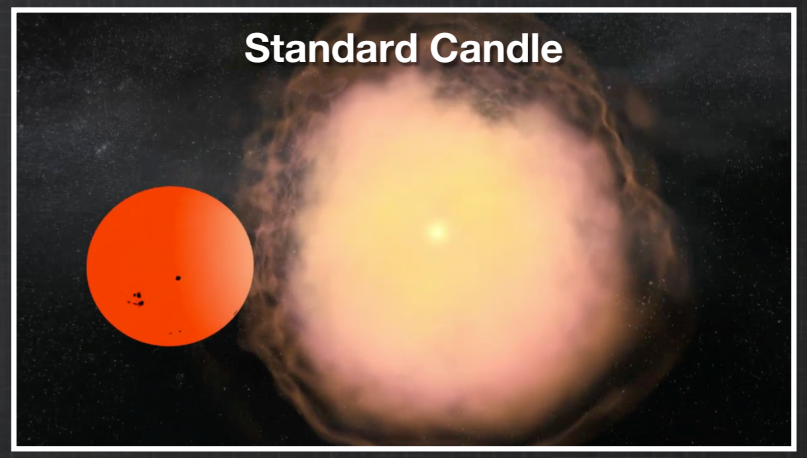




#WFIRST

WFIRST's Cosmology Roadmap





Growth of Structure
(also Expansion History)

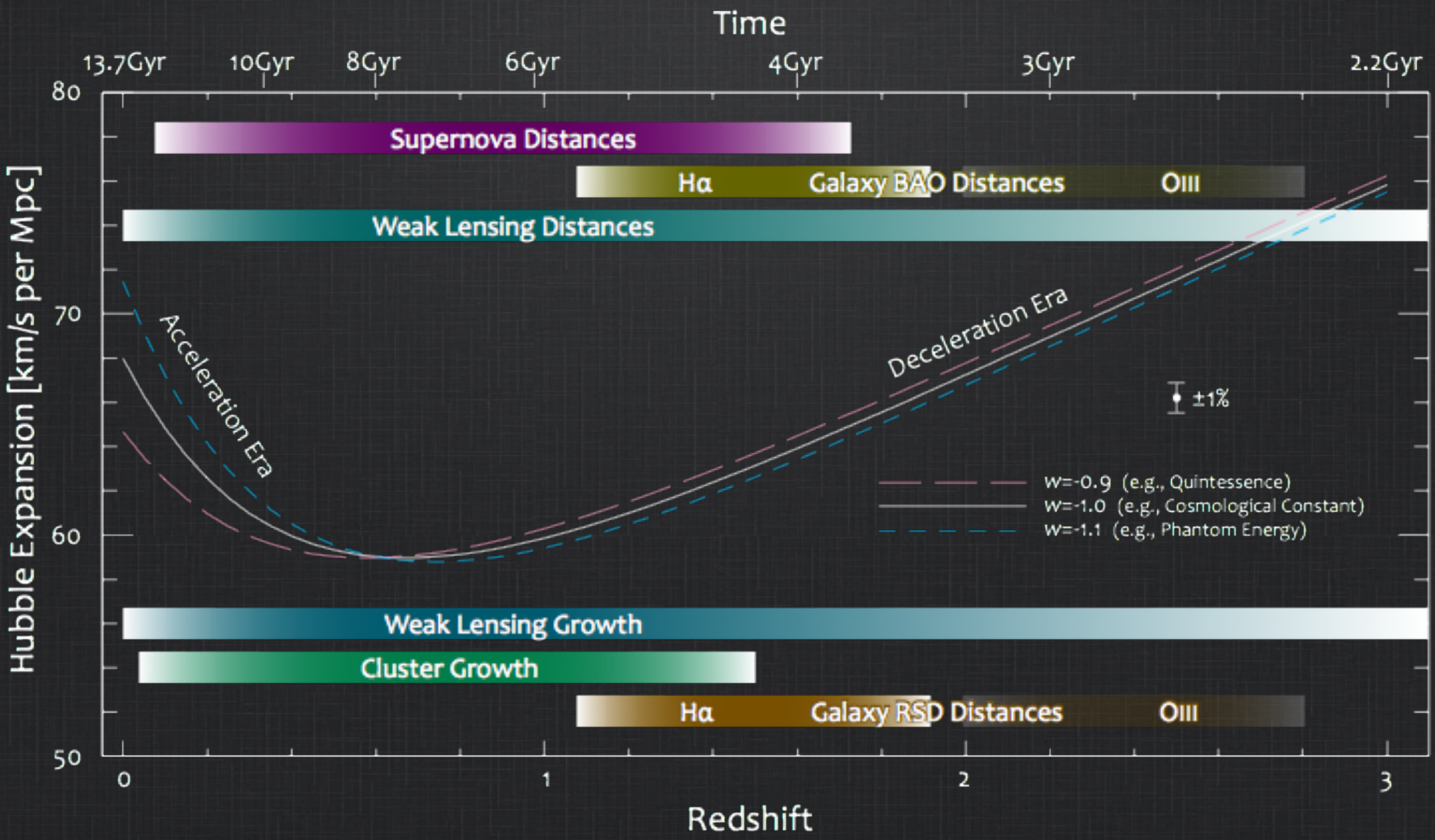
Expansion History
(also Growth of Structure)

Expansion History

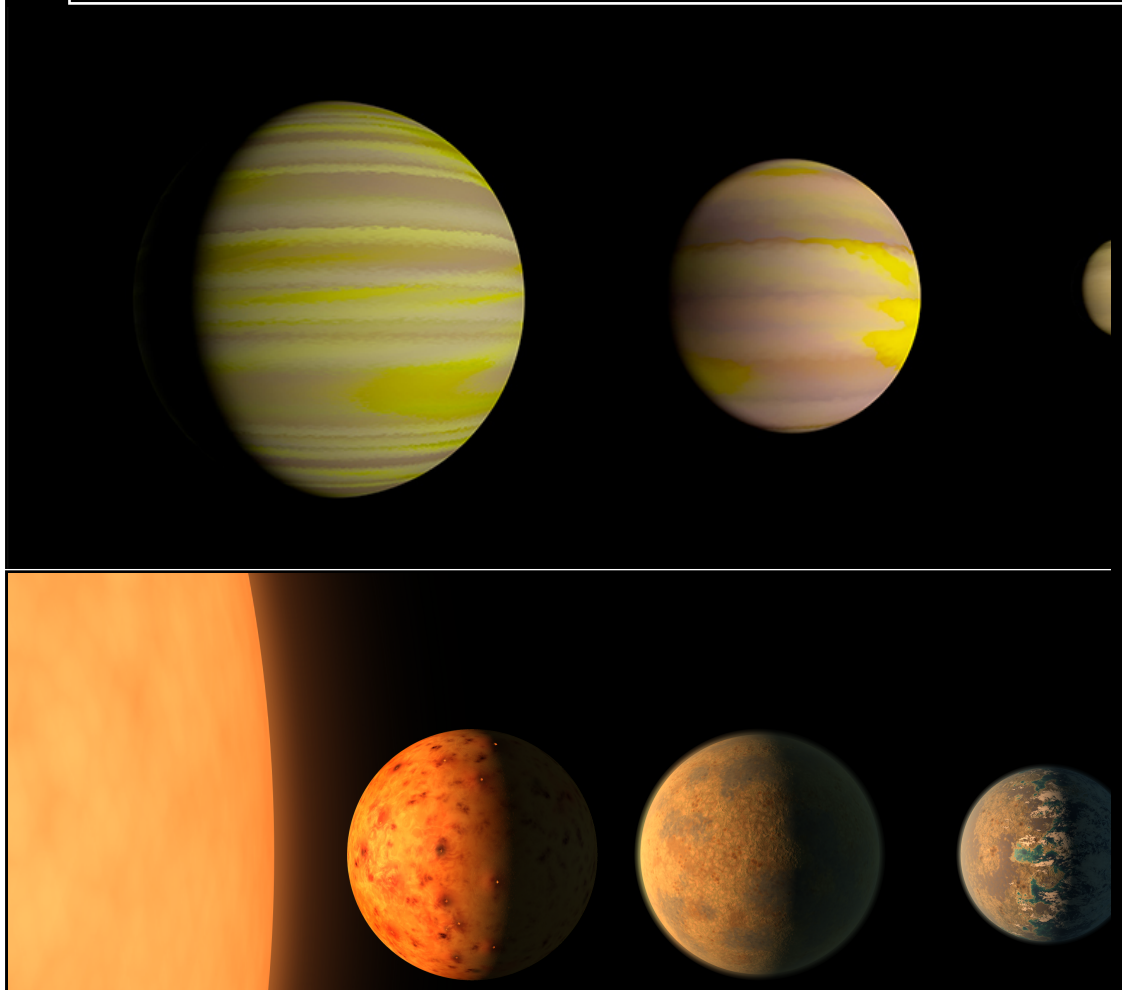
Physics of the Universe

#WFIRST

WFIRST Probes of Expansion and Growth

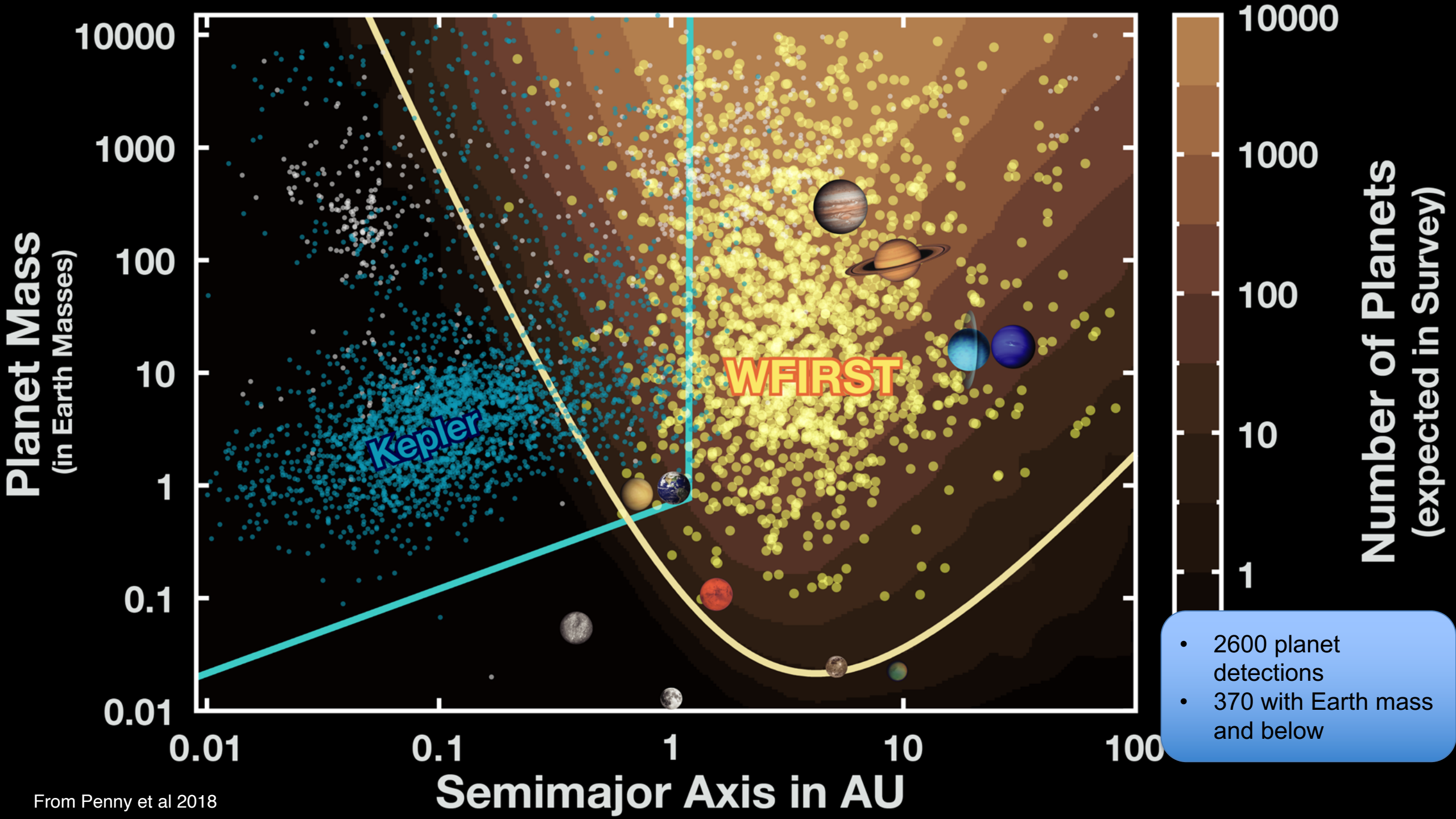


Planetary system diversity



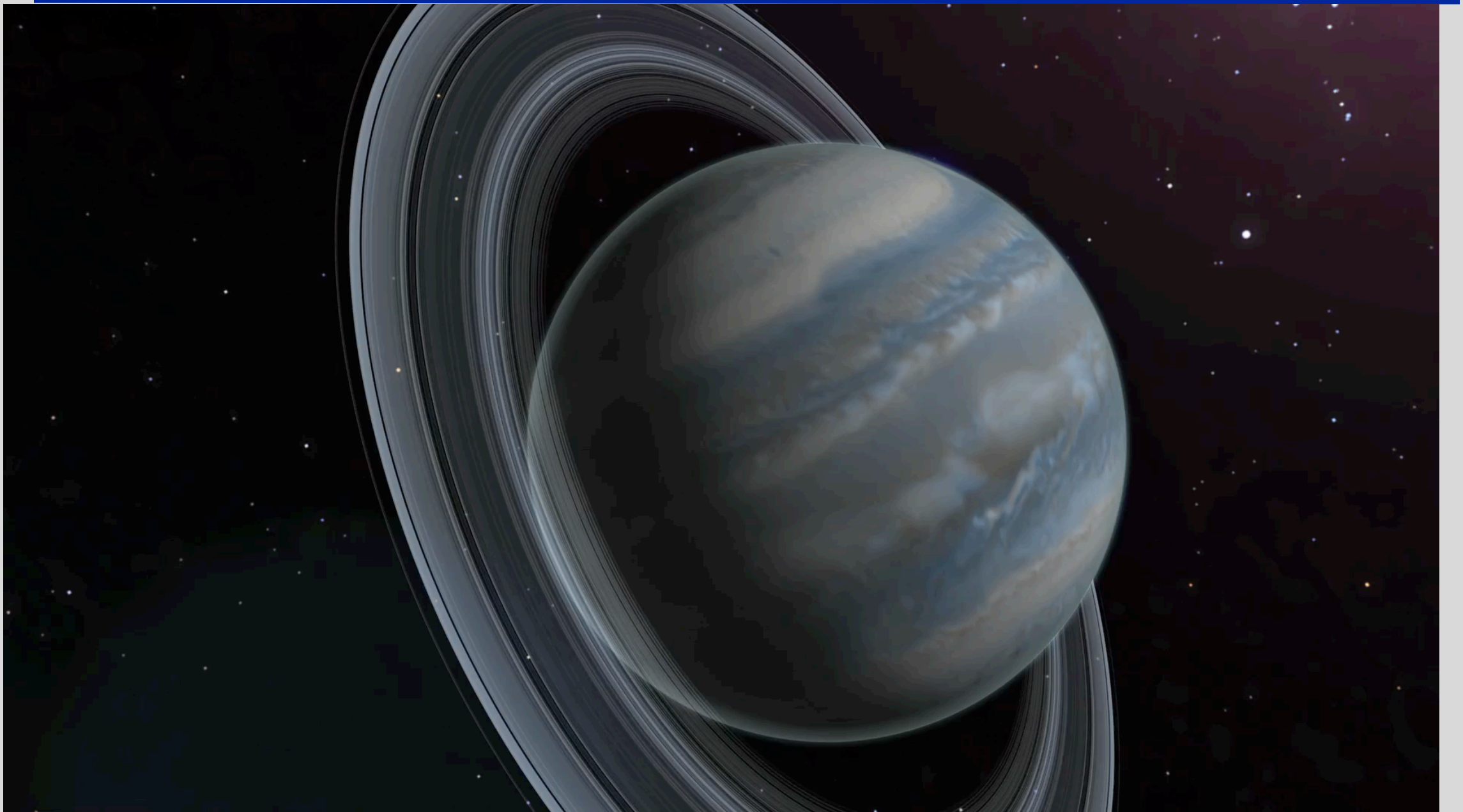
- What systems
- Are we comm
- Free-floating

Microlensing

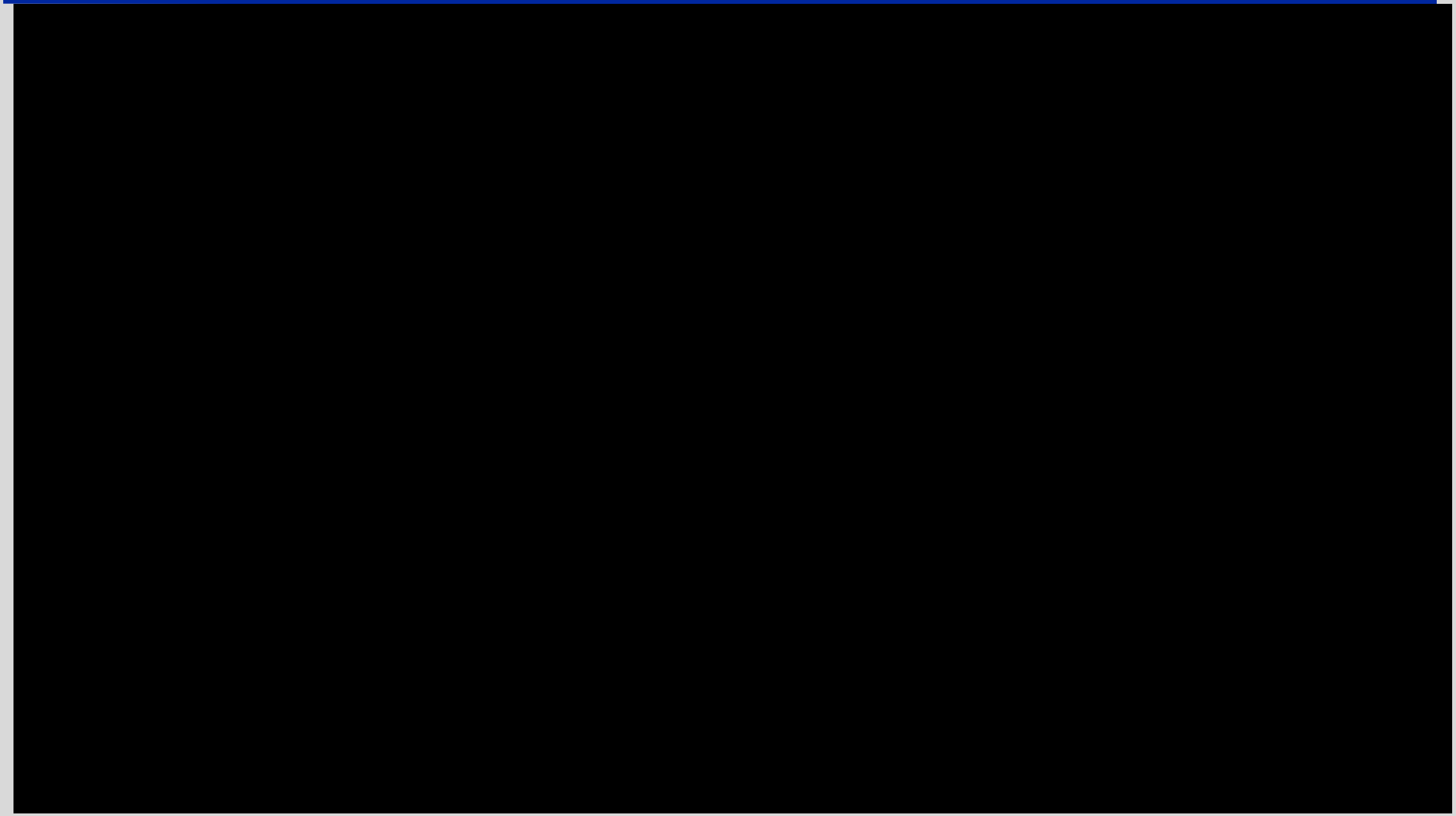


From Penny et al 2018

Coronagraphy

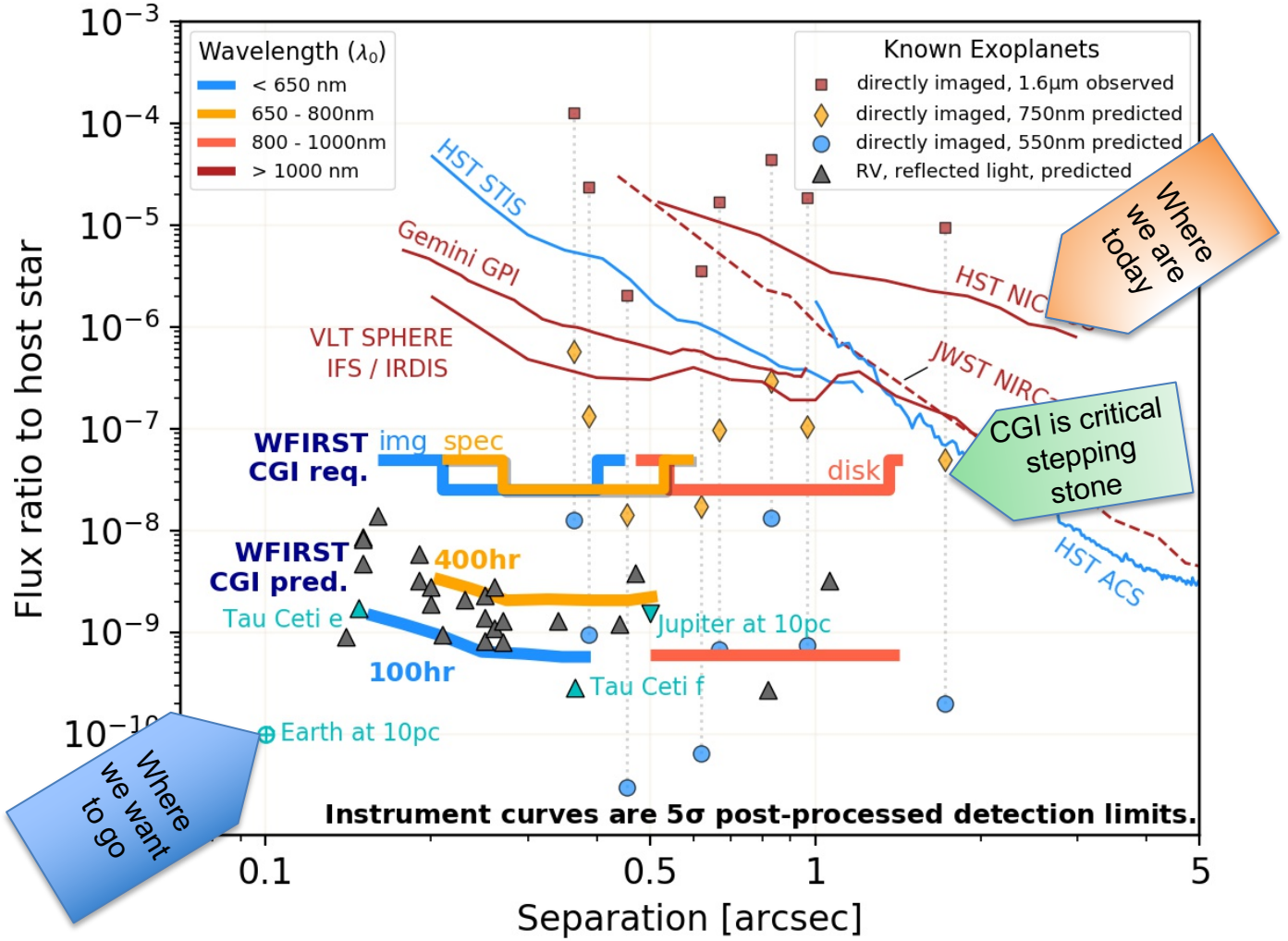


The Challenge of Coronagraphy

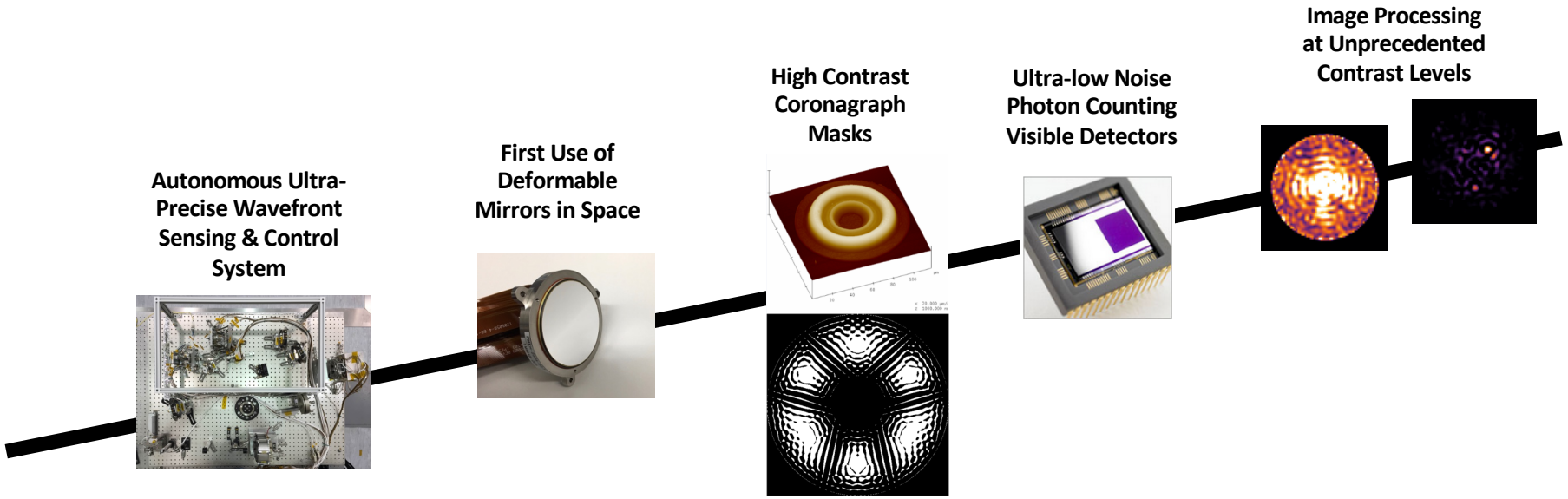


CGI is a Pathfinder for Direct Imaging and Spectroscopy of Earth-like Exoplanets

- CGI projected capabilities represent a 1000 fold compared to current capabilities
  - Enabled by active control of optical wavefront errors and pointing
- Dozens of planets within reach of characterization
- exoEarths in Habitable zone further x10-100 improvement in contrast and x2 in spatial resolution
- CGI is a major stepping stone that will obtain optical spectra of mature exoJupiters

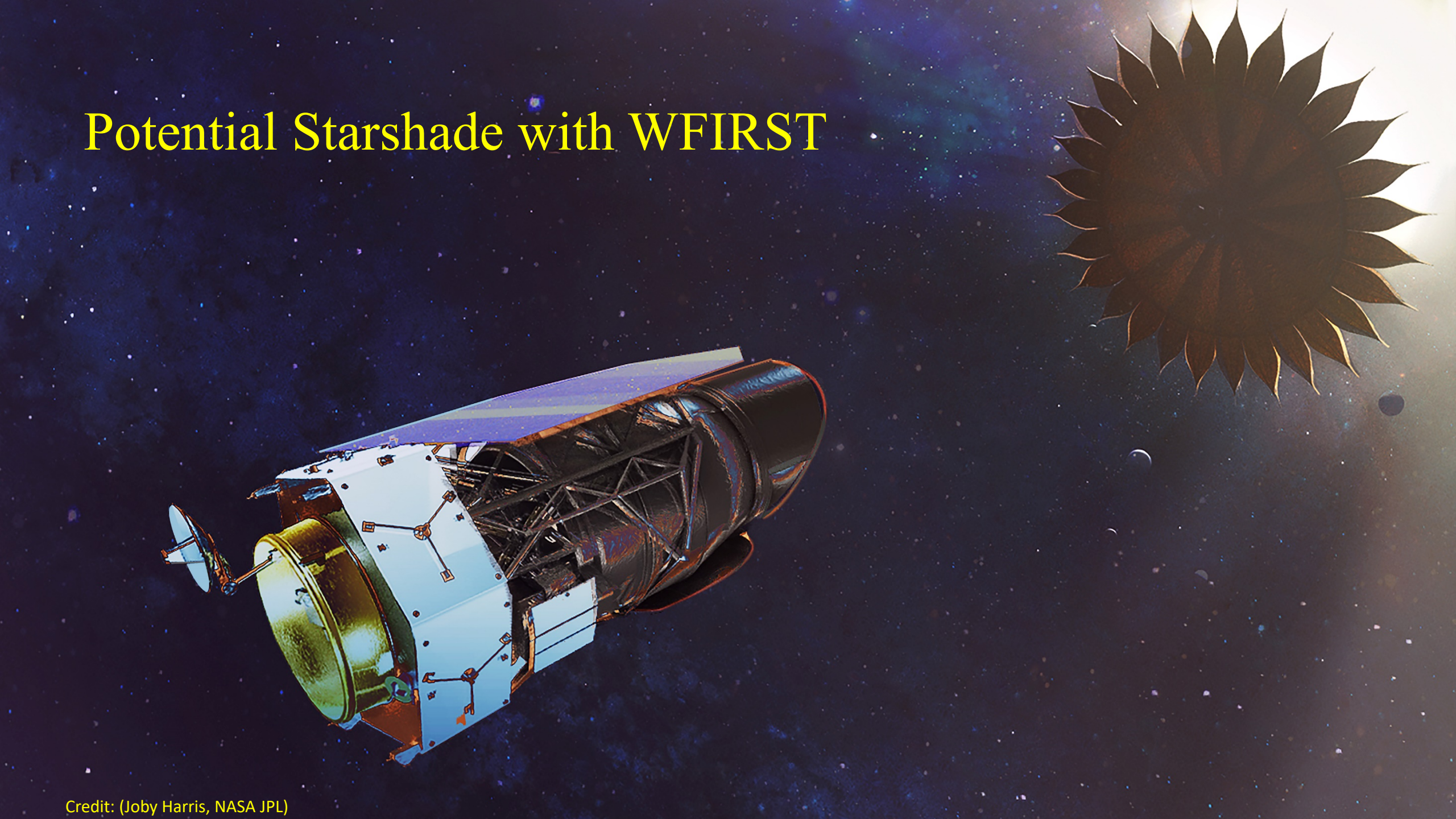


CGI Tech Demonstrations Along the Beam Path



- CGI will premiere in space many key technologies required for the characterization of rocky planets in the Habitable Zone, significantly reducing the risk and cost of future possible missions such as HabEx and LUVOIR
- CGI is a direct & necessary predecessor to these missions, and is a *crucial* step in the exploration of Sun-like planetary systems

Potential Starshade with WFIRST



Credit: (Joby Harris, NASA JPL)

Project Status

- System Requirements Review / Mission Definition Review held February 27 – March 1
  - Do we have the right requirements? / Does the mission design meet those requirements?
- KDP-B completed May 22, 2018
  - **WFIRST now in Phase B!**
  - Integral Field Channel descoped – 4/27/2018 (CSA Budget Constraints)

- White House FY2019 budget proposed termination of WFIRST to fund other priorities
- Direction from HQ is to proceed while Congress deliberates
  - *Preliminary indications are that WFIRST will be fully funded in FY2019*

- Notional schedule:
  - PDR: late 2019
  - CDR: mid 2021
  - **Launch: 3rd quarter 2025**

WFIRST Will Provide Critical Exoplanet Data and Pave the Way for a Direct-Imaging Mission

FINDING: A microlensing survey would complement the statistical surveys of exoplanets begun by transits and radial velocities by searching for planets with separations of greater than one AU (including free-floating planets) and planets with masses greater than that of Earth. A wide-field, near-infrared (NIR), space-based mission is needed to provide a similar sample size of planets as found by Kepler.

FINDING: A number of activities, including precursor and concurrent observations using ground- and space-based facilities, would optimize the scientific yield of the WFIRST microlensing survey.

FINDING: Flying a capable coronagraph on WFIRST will provide significant risk reduction and technological advancement for future coronagraph missions. The greatest value compared to ground testing will come from observations and analysis of actual exoplanets, and in a flexible architecture that will allow testing of newly developed algorithms and methods.

FINDING: The WFIRST-Coronagraph Instrument (CGI) at current capabilities will carry out important measurements of extrasolar zodiacal dust around nearby stars at greater sensitivity than any other current or near-term facility.

RECOMMENDATION: NASA should launch WFIRST to conduct its microlensing survey of distant planets and to demonstrate the technique of coronagraphic spectroscopy on exoplanet targets.

From NAS Exoplanet Science Strategy Briefing, Sept 2018

The National Academies of SCIENCES ENGINEERING MEDICINE

Partnerships

JAXA	Coordinated, contemporaneous ground-based observations on Subaru Ground station for telemetry and tracking Polarization optics for the CGI Microlensing data from the MOA project
DLR	Precision mechanisms for the CGI
ESA	Star trackers, possibly other S/C components EMCCD detectors for the CGI Ground station for telemetry and tracking
CNES	Superpolished optics for the CGI Grism data processing Cosmology simulations

Opportunities with WFIRST

- 2020 Decadal Survey will consider a Probe class Starshade
- 25% General Observer in 5 year prime mission
- ~100% GO in extended mission
- All prime survey science teams will be competed in ~2021
- All data released immediately- no proprietary period
- CGI available via a Participating Scientists Program
- Baseline mission includes contributions from ESA, France (CNES), Germany (DLR), Japan (JAXA, NAOJ)

The Questions

- What is the Universe made of (95% unknown)

- Are we alone?

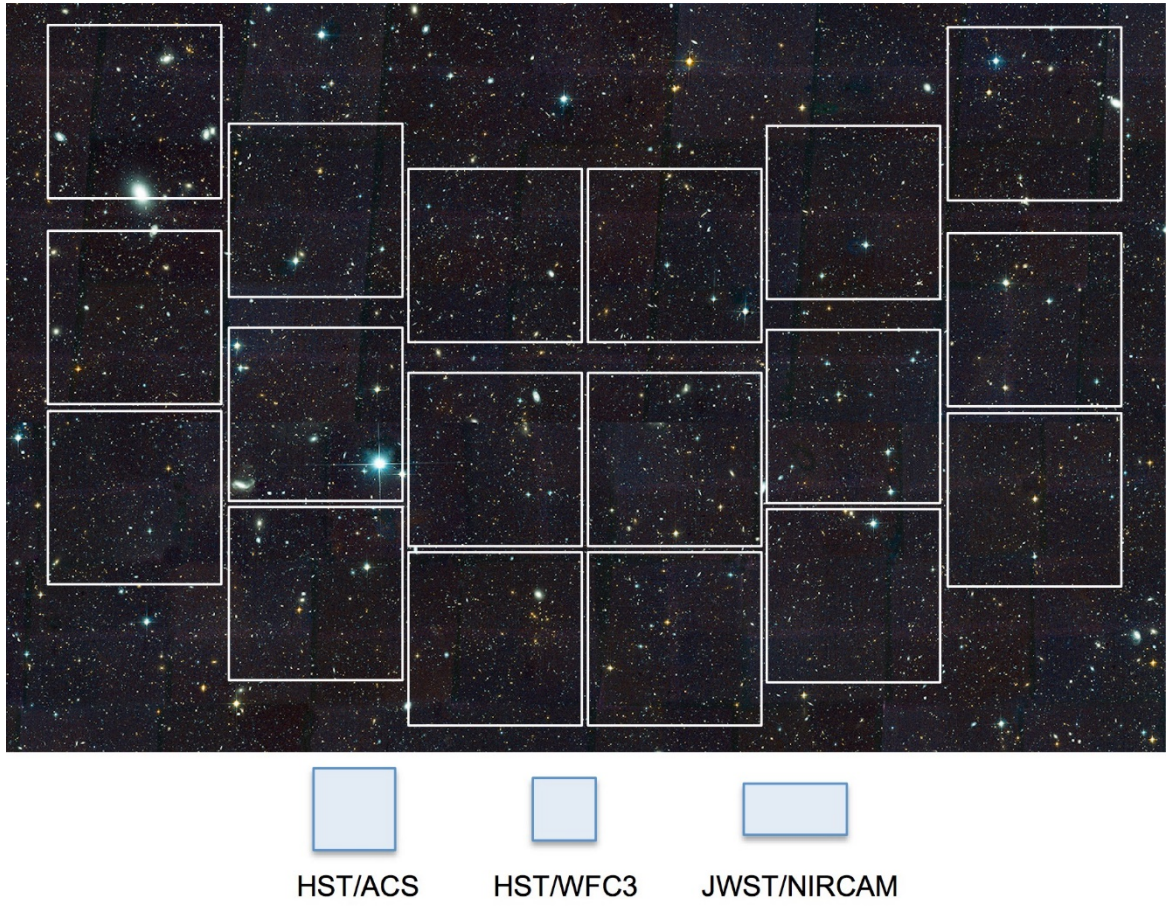
Additional Slides

SMD/APMC Direction

- Mission technical baseline unchanged, except:
  - Integral Field Channel descoped – 4/27/2018
    - CSA budget constraints
- Phase A-E cost remains at $3.2B (50% CL)
  - APD to provide “optimal” funding profile
- Notional schedule:
  - PDR: late 2019
  - CDR: mid 2021
  - **Launch: 3rd quarter 2025**

Wide-Field Instrument

WFIRST Field of View



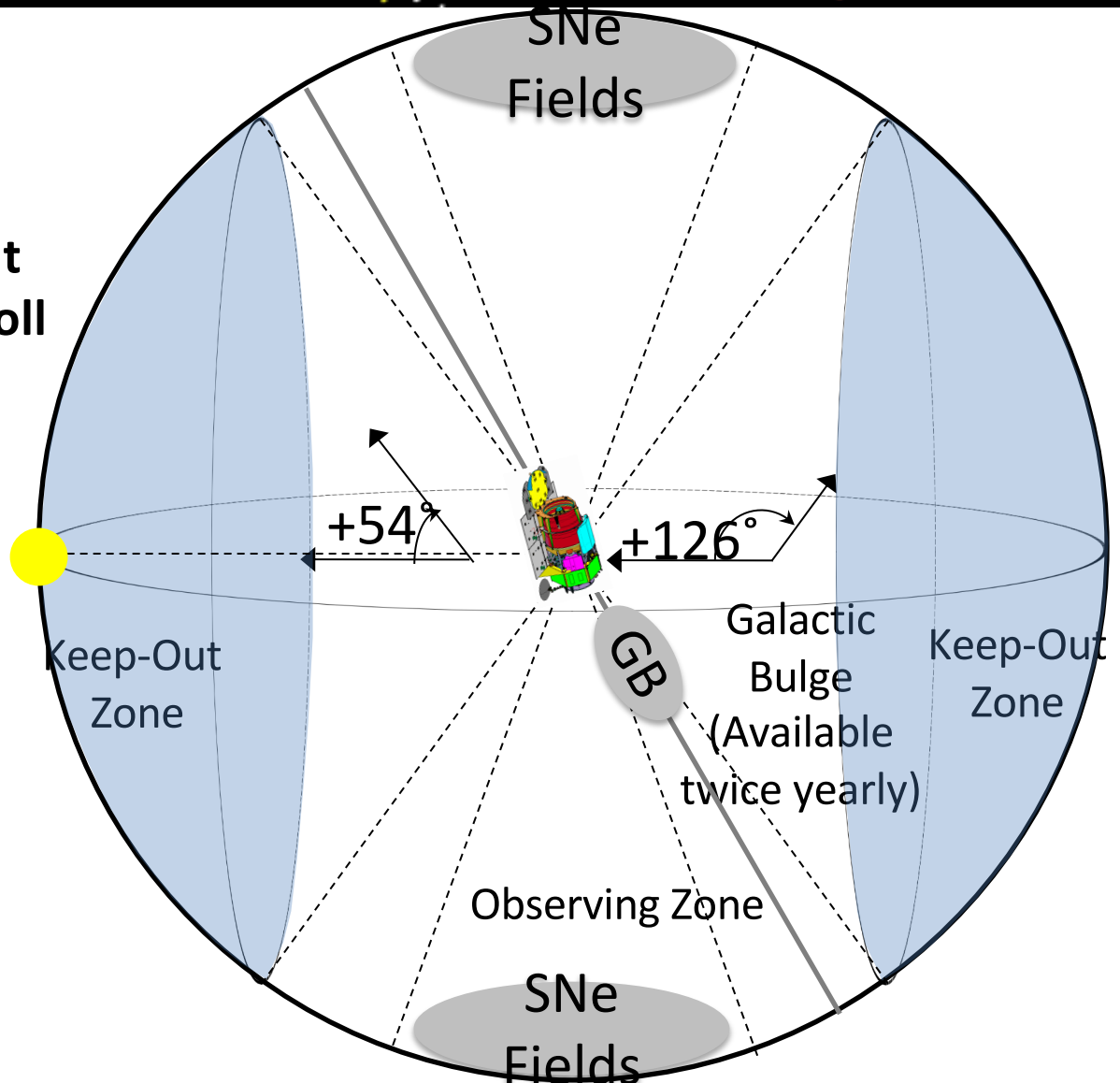
Diffraction-limited imaging
0.28 square degree FoV
0.11” pixels
R~4 filters spanning 0.48-2.0 μm
Sensitivity: 27.8 H(AB) @5σ in 1hr

Slitless grism:
1.0-1.93 μm
R: 435-865

Field of Regard (FOR)

Observing Zone:

- **54˚-126˚ off Sun Line**
- **360˚ about Sun Line**
- **±15˚ about line of sight (LOS) off max power roll angle**



SNe fixed fields ±20˚ off of the ecliptic poles, located in continuous viewing zone

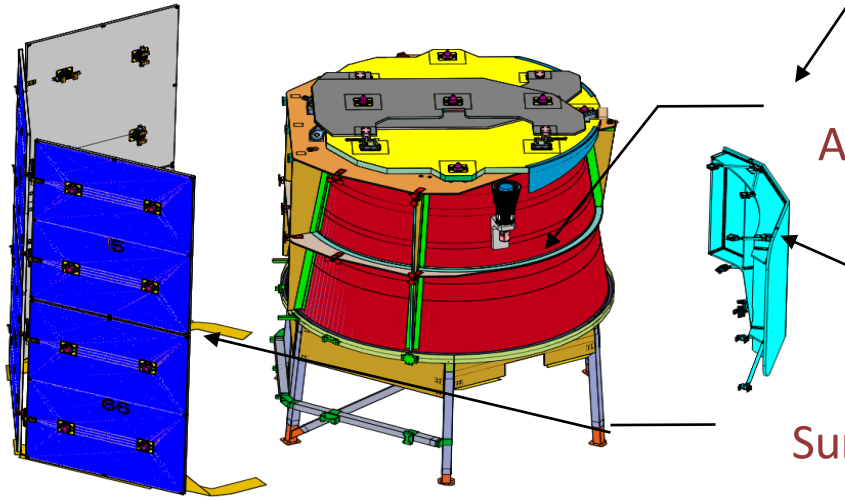
Earth/Moon LOS avoidance angles are a minor sporadic constraint

HLS/GO/Coronagraph observations can be optimized within the full Observing Zone

Microlensing can observe inertially fixed fields in the Galactic Bulge (GB) for 72 days twice a year

Observatory Expanded View

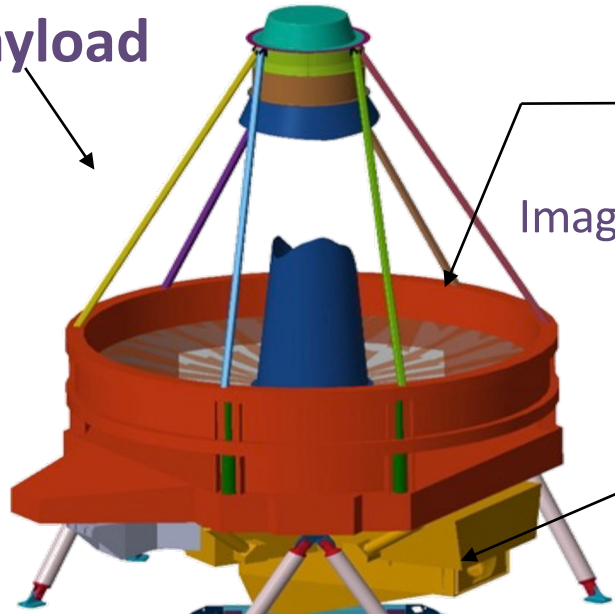
Observatory = Spacecraft + Payload



Outer Barrel Assembly (OBA)

Facility Cryo Radiator

Solar Array Sun Shield (SASS)

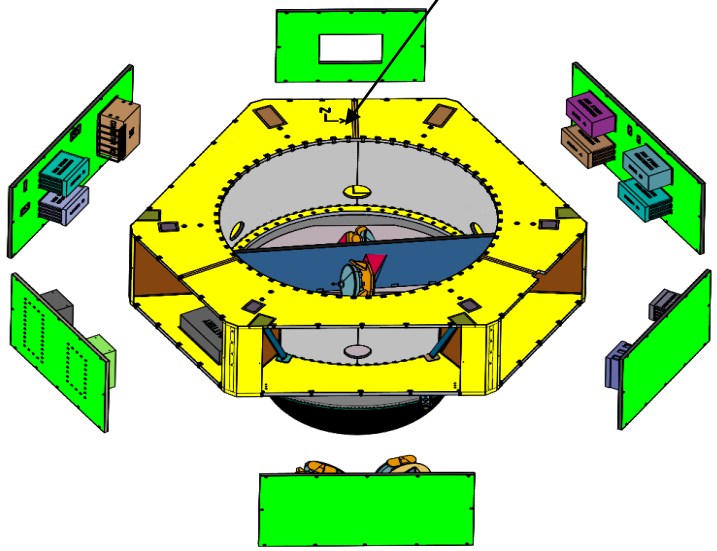


Forward Optics Assembly (FOA)

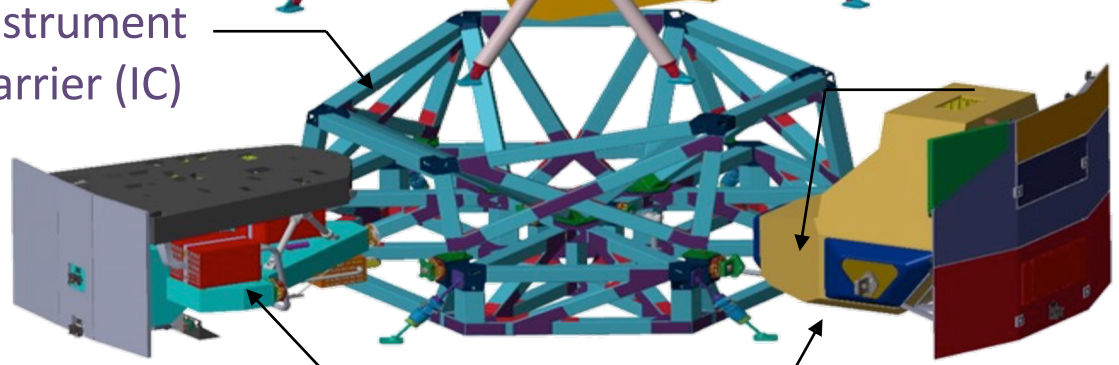
Imaging Optics Assembly (IOA) = FOA + AOM

Aft Optics Module (AOM)

Spacecraft Bus (S/C)



Instrument Carrier (IC)



Coronagraph Instrument (CGI) (outer enclosure not shown)

Wide Field Instrument (WFI)